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Design of Solar LED Lighting System Controller Based on 51 Single Chip Microcomputer

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Abstract: With the promotion of the awareness of energy conservation and environmental protection, solar LED lighting system, as the representative of green lighting, has received widespread attention. However, the intelligent performance of the existing system controller is insufficient, which limits its practical application effect. The purpose of this paper is to design a solar LED lighting system controller based on 51 single chip microcomputer. Through optimizing the hardware and software design, the intelligent control level, energy efficiency and reliability of the system are improved to meet the needs of different application scenarios.

Keywords: Solar LED lighting; 51 single chip microcomputer; controller design; energy efficiency optimization.

1. Introduction

Solar LED lighting system shows great potential in the field of lighting by virtue of its characteristics of environmental protection and energy saving. However, the intelligent performance of controllers in the current market is limited, which cannot meet the growing demand for intelligence. Therefore, the design and optimization of solar LED lighting system controller is particularly important. Through in-depth design of the controller, this research aims to improve the overall performance of the system and provide technical support for the promotion and application of solar LED lighting systems.

2. Design of Light Emitting System

2.1. Design of solar panel and its main control circuit

Solar panel is the core part of the system, which directly affects the energy capture efficiency. In this paper, monocrystalline silicon solar panel is selected, and its power output, conversion efficiency, durability and cost are comprehensively considered. In the design, multiple panels are arranged in parallel to improve the energy capture efficiency, and an adjustable angle bracket system is designed to maximize the capture of solar energy [1,2]. At the same time, it ensures the fixation mode and windproof performance of the battery panel and bracket, and ensures the stable operation of the system in bad weather. The main control and data circuits are shown in Figure 1.

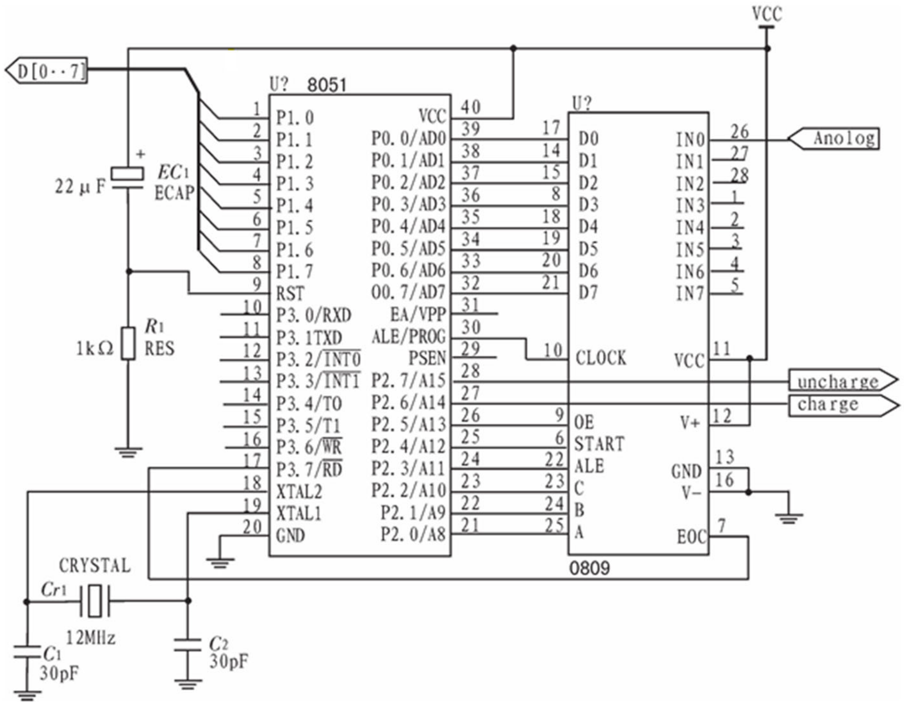

Figure 1. Solar main control circuit diagram

2.2. Design of battery energy storage

Battery energy storage system is related to the stability and reliability of the system. In this paper, lithium battery is selected as the energy storage device, and the capacity, cycle life, discharge depth and self discharge rate are comprehensively considered. The series and parallel combination mode is adopted to meet the system's demand for voltage and capacity. The balanced charge and discharge management system is designed to ensure that the voltage and capacity between cells are balanced and avoid instability.

2.3. Design of charge and discharge control system

The charge and discharge control system is the key part of the system. The charging control adopts the combination of constant current charging and constant voltage charging to improve the charging efficiency and protect the battery. At the same time, the charging current and voltage are accurately controlled according to the real-time monitoring of lighting conditions and battery status. The discharge control adopts the combination of constant current discharge and constant voltage discharge to provide stable output current and voltage, and accurately control the discharge current and voltage according to the real-time monitoring of load changes and battery status. Figure 2 shows the charging and discharging control circuit.

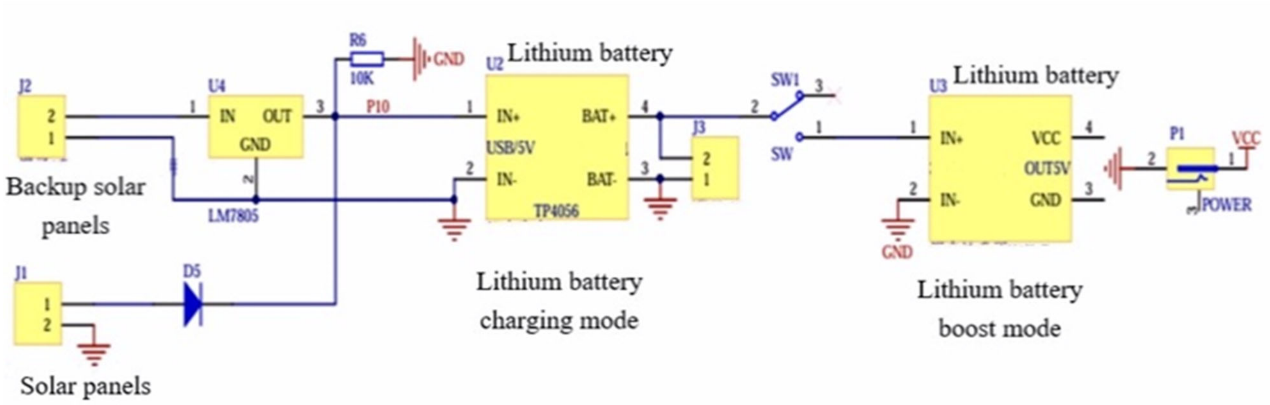

Figure 2. Charging and discharging control circuit

3. Design of LED Lighting System

3.1. LED module selection and layout

LED module selection comprehensively considers luminous flux, color temperature, color fidelity and luminous angle, and selects 5050 LED module as the light source to meet the requirements of lighting quality and range. The layout adopts the distributed mode, and the LED modules are evenly distributed to ensure the uniformity of light and lighting effect. At the same time, optimize the layout position, improve the utilization rate of light energy, and avoid energy waste and insufficient light.

3.2. Design of optical control system

The light control system realizes the automatic light adjustment of the lighting system. The photosensitive resistor is introduced as the light sensing element to detect the light intensity in real time and control the LED lighting system intelligently. Constant current drive scheme is adopted, combined with carefully designed circuit structure and optical control algorithm to achieve precise control. Automatically adjust LED brightness when the light is weak; When the light is sufficient, automatically turn off the LED module to save energy. In addition, the parameter adjustable function of the light control system is designed to meet the needs of different lighting conditions and improve the flexibility and applicability of the system.

4. Design of Controller Hardware

4.1. Type selection and function design of single chip microcomputer

51 single chip microcomputer with high performance and stability is selected as the core chip of the controller to meet the complex control requirements of the system. In the functional design, the real-time, stability and scalability of the system shall be fully considered. A variety of timers and PWM output channels are designed to realize the brightness adjustment and flicker control of LED lights. Figure 3 is the minimum system circuit diagram of the single chip microcomputer.

4.2. Design of peripheral circuit

In terms of power management, efficient solar photovoltaic battery charging circuit and regulated power module are used to ensure that the controller works normally under different lighting conditions and provide stable power support for LED lighting system. The power management module is designed to realize the dynamic power regulation of LED lights, reduce the system energy consumption and extend the service life of photovoltaic cells. In the sensor interface design, the interface circuit design and signal processing algorithm are considered to ensure that the sensor accurately and stably collects the ambient light and temperature data and transmits them to the MCU for processing. At the same time, efficient LED driving circuit and stable and reliable communication interface circuit are designed to ensure stable operation of LED lights and reliable communication between the controller and external equipment [3].

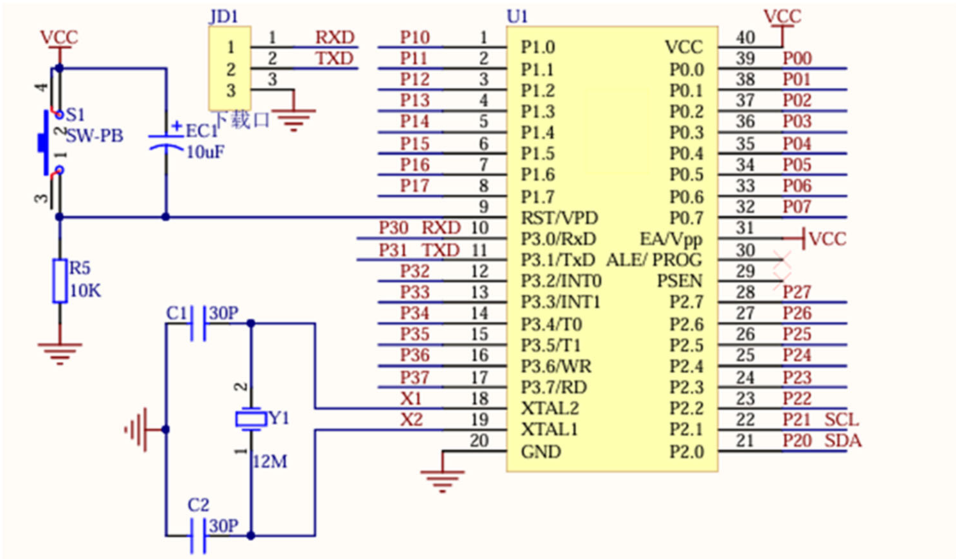

Figure 3. Microcontroller minimum system circuit diagram

5. Design of Controller Software

5.1. Design of control algorithm

In software design, the design of control algorithm is very important. The control algorithm based on 51 single chip microcomputer is adopted to realize the intelligent control of solar LED lighting system. Firstly, the photoelectric characteristics of the solar panel are modeled, the solar radiation intensity, temperature and other factors are monitored in real time, and the output power is calculated with the model. Then, according to the brightness demand of LED lamps and the current ambient lighting conditions, the algorithm is used to dynamically adjust the brightness and working status of LED lamps to achieve energy-saving and efficient lighting effects [4,5]. At the same time, the intelligent light control algorithm is used to monitor the ambient light in real time and adjust the brightness of LED lamps intelligently to achieve the best lighting effect.

5.2. System status monitoring and protection

System status monitoring and protection is an important guarantee to ensure the safe and stable operation of the system. A well-designed system status monitoring and protection mechanism, including real-time status monitoring and protection measures for key components such as solar panels, charge and discharge control modules, LED lamps, etc. Through software design, key parameters such as solar panel output power, charging and discharging voltage and current, LED lamp brightness, etc. can be monitored in real time and fed back to the controller software for analysis and processing. At the same time, the state protection algorithm is designed to take protection measures in time to avoid damage when the system state is abnormal. In addition, environmental parameters such as temperature and humidity of the system are monitored to ensure stable and efficient operation of the system under different environmental conditions.

6. System Integration and Commissioning

6.1. Hardware system integration and debugging

In this process, the solar panel is connected to the charging control module through the X-type connection mode, and has undergone strict testing to verify the stability and reliability of its connection. The adaptability and stability of the system under various conditions are further tested by adjusting the lighting conditions and simulating different working environments. At the same time, each module of LED lighting system, including light source, power management and light control module, is integrated and debugged. Through detailed electrical parameter test and adjustment of brightness and color temperature, the system performance can be ensured to meet the expectations. In addition, the connection between the 51 MCU controller and each hardware module has also been carefully designed and tested to verify the cooperation between the modules through communication protocols and data transmission, as shown in Figure 4. The input/output interface, sensor connection and power management of the controller shall be fully debugged to ensure the stability and reliability of the controller and the whole system.

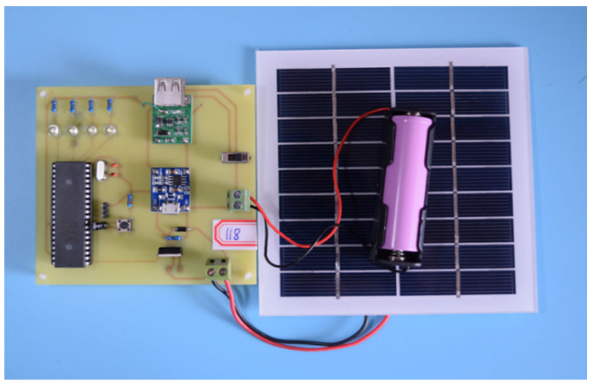

Figure 4. Design hardware picture

6.2. Software system integration and debugging

In the software system integration stage, the software system of the controller is fully integrated and debugged. The charging management of the solar panel, the brightness and color temperature control of the LED lighting system, the data acquisition of the light sensor and other functions are realized through programming, and the stability and reliability of the controller software system are verified by simulating different working scenarios for detailed testing. Figure 5 is the system program flow chart.

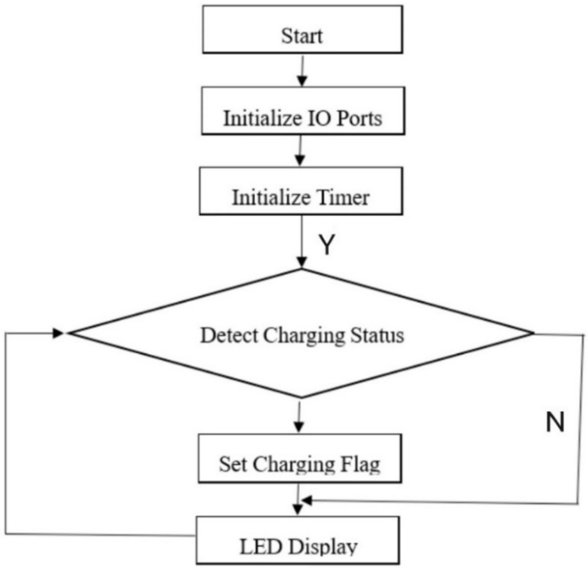

Figure 5. System program flow chart

6.3. Software system integration and debugging

First of all, it is necessary to conduct a comprehensive functional performance test of the system, covering the charging efficiency of solar panels, the brightness and color temperature regulation of LED lighting, and the intelligent control function of the controller, and analyze the results in combination with the simulation test diagram (as shown in Figure 6). Secondly, verify the stability of the system by simulating various environmental conditions, evaluate its ability to cope with abnormal conditions, and optimize the system stability accordingly. Finally, comprehensively evaluate and optimize the system energy efficiency, including solar panel charging efficiency, LED energy consumption and controller power consumption, to improve the system energy efficiency performance and energy-saving effect, and ensure the reliable operation of the system under various conditions.

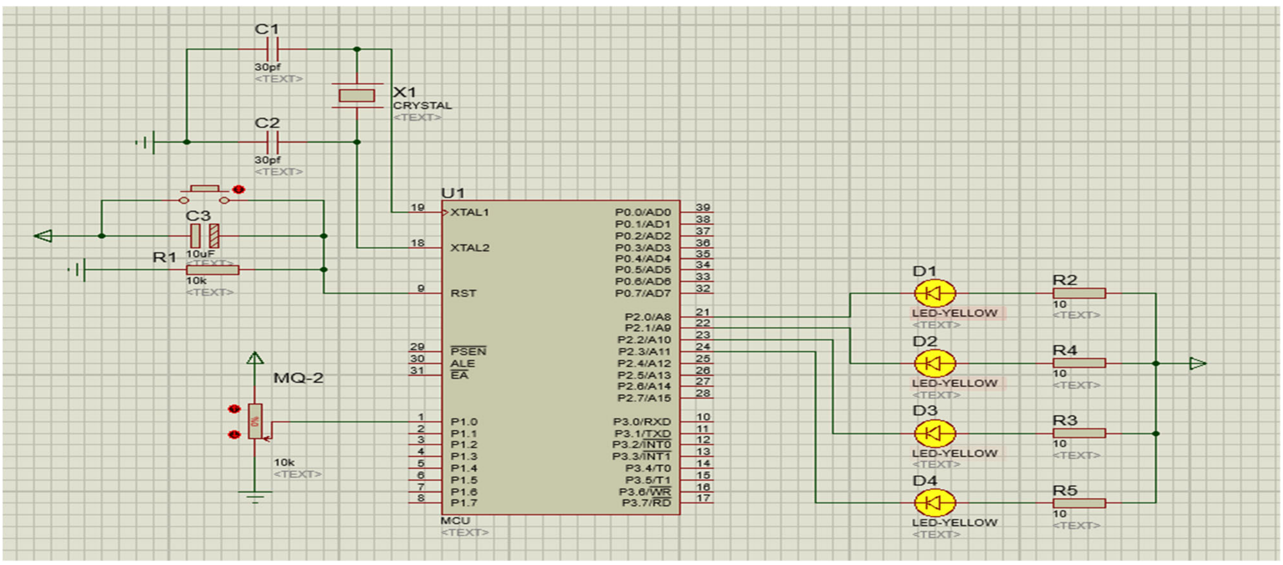

Figure 6. Simulation test diagram

7. Summary

Through in-depth design of solar LED lighting system controller, this paper optimizes the light emitting system, LED lighting system, controller hardware and software design, system integration and debugging. In the design of the light emitting system, full consideration is given to the solar illumination conditions and light intensity changes. The solar energy is converted into electric energy through the photoelectric conversion device to ensure the efficient operation of the system. In the design of LED lighting system, high brightness LED lamps are used. Through reasonable optical design and circuit design, high brightness and energy-saving effects are achieved. In the hardware and software design of the controller, 51 single chip microcomputer is selected as the main control chip, and intelligent control and management of the lighting system are realized through carefully designed hardware circuits and software algorithms. In the system integration and commissioning phase, the stability and reliability of the controller were fully verified, and the normal operation of the system was ensured. This research provides an important theoretical and practical basis for the intelligent control of solar LED lighting system, and is expected to promote the further development and application of solar lighting technology.

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